Preparing Teachers for the 21st Century Using PBL as an Integrating Strategy in Science and Technology Education

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Abstract
This paper explores the foundational principles of Problem-Based Learning (PBL) as an integrative teaching strategy designed deliberately to cross discipline boundaries in order to make meaningful and lasting connections. The authors suggest that while PBL has in recent times has largely manifested towards a method of inquiry within a single discipline the founding principles and key characteristics that inform PBL may be applied to solving technological inquiry where an understanding and application of scientific principles is fundamental in informing and developing the preferred solution. This paper highlights that in order to be effective classroom educators, in an ever increasing and complex world, pre-service teachers' need to develop robust mental models and metacognitive skills that are transferable. In supporting this development the rationale and the application of PBL as an integrated teaching and learning strategy in pre-service science and technology education will be examined. This paper suggests that PBL is an effective strategy in supporting inquiry of an interdisciplinary nature as well as developing dispositions that embrace collaborative inquiry and reflective practice.

Key words
Problem-based learning, technology education, science education, pre-service teacher education, dispositions, metacognition, reflective practice

Introduction
As citizens of the world we live in a rapidly changing and advancing knowledge based society where we are called upon to constantly solve complex issues on a daily basis, issues that require the ability to think and act by accessing a broad spectrum of knowledge bases (Askwell-Williams, Murray Harvey & Lawson, 2005; Mulchay, 2006; Tan, 2007). Based on the premise of connecting theory to practice one of the greatest challenges in pre-service teacher education is to foster students' abilities to integrate their learning over a period of time employing metacognitive strategies in order to meet those challenges in the 21st century classroom.

Learning that assists in developing integrative and metacognitive capabilities is considered important because it assists in developing habits of mind in preparing students to make informed choices relating to complexities in conducting personal, professional and civic life (Huber & Hutchings, 2008). The idea that integrative learning depends on students to make connections has a long tradition. The burden of integration has traditionally fallen on the learners to make the connections between fragmented experiences by themselves.

What is new, according to Huber and Hutchings (2008), is a conviction that 'intentional learning' is a capacity educators should explicitly explore in teaching. Several core principles inform this conviction. Intentional learning, which is steeped in the philosophies of Dewey, has a deep sense of purpose in how it connects the fragmented and the disconnected. It seeks to develop an understanding of the self as a learner with a heightened understanding of the processes involved and goals as learners. Intentional learning enhances the ability to ask deep questions and to synthesise and evaluate information. Huber and Hutchings assert intentional learning entails cognitive processes that have learning as a goal rather than an incidental outcome (2008). Advocates of this approach point to the power of 'explicit goals', goals to which students themselves have negotiated input, thus enhancing the ownership and intrinsic value of learning.

Intentional learning can also be viewed through the lens of reflection in practice. The need for reflective practice in teacher education has been argued on the grounds that it highlights the connection between thought and action as a key foundation of learning in which doing and thinking are interrelated (Schon, 1983). Schon argues, by reflecting "we can make new sense of…situations of uncertainty or uniqueness…" (1983, p. 61).

The idea of engaging with intentional, integrative learning was an important consideration as the curriculum design team considered possible strategies to support deep learning of the students in the pre-service teacher education course 'Integrated Science and Technology Curriculum' in the Bachelor of Education (Teaching) Primary Degree at Massey University College of Education. Problem-Based Learning, as highlighted in this paper is strategically designed to foster the intentional development described and contribute significantly to the professional development of the pre-service teacher and subsequent classroom practice.

MacIntyre, Brears & Bhattacharya (2006) report, that in 2001 the New Zealand Ministry of Education developed and implemented a national literacy and numeracy strategy for primary schools. Many schools responded to this

strategy by organising their literacy and numeracy programmes in the morning slots with the other five curriculum disciplines relegated to the afternoon slots under the guise of 'integrated studies' or 'inquiry learning'. With a national emphasis on numeracy and literacy and the adoption of national standard testing for both numeracy and literacy in 2009 the pressure towards integrated curriculum will not abate. The requirement for preparing pre-service teachers for teaching in an integrative manner becomes a vital component, not to address the Ministry initiatives per se, but more importantly to address the learning needs of the students for the 21st century.

The appropriate pedagogical approach

The focus of this paper, an integrated Curriculum Science and Technology course is informed by a number of principles aimed at enhancing the learning experiences of the pre-service teachers to meet the curriculum requirements in their future classroom teaching practice. Prior to this course, which takes place in the third year of study; initial education teachers have taken a specialist technology course in the first year and a specialist science curriculum course in the second year. As well as furthering the understanding of the nature of science and technology this course advances an understanding of metacognition and the development/enhancement of Information and Communication Technology skills through the application of PBL as the strategy for collaborative inquiry at the interdisciplinary level of curriculum integration.

Problem-based learning is situated within the domain of inquiry-based learning. Central to all forms of inquiry-based learning according to Justice et al (2002) is self reflection and evaluation. PBL as an inquiry-based learning strategy, is characterised by its encouragement of collaborative group work; an emphasis on analysis, evaluation and focus on reflection as integral components of practice (Goransson, 2007; Putnam 2001). Gallagher et al. (1995 cited in Ward & Lee, 2002) note three features that set the parameters of the PBL strategy: "initiating learning with a problem, making exclusive use of ill-defined problems and using instructors as metacognitive coaches" (p. 18). In the research investigation students were required to work within groups of three to develop an outcome in response to a self-generated problem or issue of concern over a five week period. Assessment of the group electronic presentations include a section titled 'Self reflection and Evaluation' of the PBL process.

Tambyah (2008) asserts that the role of primary teachers are distinctive from that of their secondary counterparts in that they are generally responsible for teaching across the curriculum, rather than in specialist areas, where in general the teachers have a greater in-depth understanding of the discipline. Due to the requirement to teach across the curriculum it is understandable that discipline knowledge is weaker with Bencze (2010) asserting elementary (primary) school teachers often lack a robust level of pedagogical self efficacy for teaching science and technology. He suggests pre-service teachers on teaching practicum are particularly anxious about implementing open-ended inquiry of a scientific, technological or interdisciplinary nature. In response to concerns of this nature the authors concluded that engaging in a supportive and structured PBL environment after engaging in distinct and separate learning in both science and technology courses would develop the level of self efficacy required to support the future teaching of these two learning areas with the ability and experience to seek the assistance of experts in the wider community to support the inquiry.

Historical overview of Problem-Based Learning

The notion of learning through solving problems is not new and is indeed embedded deeply within higher education circles. The twentieth century, according to Savin-Baden and Major (2004), was an era marked by criticism and accountability in higher education. Internationally educators mooted for changes away from the dominant transmission mode of teaching. The development of knowledge began to be viewed as process by which individuals grappled with complex questions, conduct original investigations and filter information through the realms of social and cultural contexts (Savin-Baden & Major, 2004). The negotiation of meaning, the focus on experience and the development of sound social practices and ideologies began to be viewed as central to constructing knowledge.

Much has been written about the development (Gallagher, 1997) of the pedagogical strategy: Problem-Based Learning (PBL) and its intentions in tertiary education to address the concerns raised (Duch, Groh & Allen, 2001; Kolmos, 2002; Major & Palmer, 2001; Peters, 2006; Savin-Baden and Major, 2004; Ward & Lee, 2002). Savin-Baden & Major (2004) report Donald Woods of McMaster University has been credited with coining the term 'Problem-Based Learning', with two McMaster University academics, Barrows and Tamblyn being instrumental in ensuring the early success of PBL.

PBL was originally designed for use in the medical profession to provide students with experiences in drawing upon a range of disciplines to make accurate diagnosis during their practicum (Barrows & Tamblyn, 1980). It was noted that young physicians were graduating with a wealth of knowledge but not necessarily the problem solving skills to use that information appropriately in diagnostic

assessment (Ward & Lee, 2002). During the PBL practicum students generated knowledge in an attempt to define the condition identified in the 'problem pack' (Savin-Baden & Major, 2004) by drawing upon specific areas such as neurology and physiology, not in isolation but by seeking connections to the contributing knowledge bases to inform a diagnosis. When compared with a control group, students who engaged in the PBL process were seen to have increased motivation, problem solving and self-directed study skills (Barrows & Tamblyn, 1980).

As a natural progression PBL has been used with increasing frequency in Higher Education to train professionals across a wide spectrum. Examples of the application of PBL can be found in the literature about professions as diverse as architecture, arts, education, humanities, law, science, mechanical engineering social work and psychology (Duch, et al, 2001; Kain, 2003; Kolmos, 2002; Peters, 2006; Savin-Baden & Major, 2004).

From the mid 1990s PBL has attracted the attention of teacher educators. It has long been recognised that tensions exist between the practices promoted in teacher education programmes and the practice of the beginning teacher (Mulcahy, 2006). Feedback from students according to Murray-Harvey & Slee (2000) pointed to an enduring disconnection between institutional learning and the 'real' world of teaching. Shulman (1998) suggests a tense relationship exists between theory and practice. He emphasises the importance of pedagogies that foster combining theory and practice in local, situated judgements, giving particular attention to case studies. Shulman asserts case studies confront novice practitioners with experiences that draw upon theory and practice where moral and ethical decisions need to be made and action taken. Shulman argues "Options are rarely clean; judgements must be rendered" (1998, p. 525). PBL has been considered an important means of bridging the gap exposing pre-service teachers to the complex situations they will encounter as professional educators while simultaneously capturing the essence of constructivist and social constructivist learning theories in theory and practice (Askell-Williams, Murray-Harvey & Lawson, 2005; Edwards & Hammer, 2007; Peters, 2006).

Philosophical foundation

The philosophical foundation for PBL aligns to cognitive theories argued by the American philosopher John Dewey. For Dewey, knowledge is a reflective or intellectual grasp of a situation, which grows out of, but is not identical with, experience (Dewey, 1916 as cited in Duch et al, 2001) Dewey argues,…"careful inspection of methods which are predominately successful in formal education…will reveal that they…give pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; learning naturally results" (Duch, et al, 2001, p. 179). Experience, because of its diverse nature, presents conflict or problems that an inquiry seeks through analysis and the development of hypothesis or modelling to resolve. The acquisition of knowledge according to Savin-Baden and Wilkie (2004) is embedded in the experimental, practical and active engagement that challenges students to assess situations both from an analytical and critical perspective to inform a proposed outcome.

The enhancement of learning as described by Dewey is fundamental to PBL. Proponents of PBL suggest that the majority of students will enhance both their knowledge and skill base by accessing and developing these aspects throughout the duration of the inquiry. This aligns to educational research which suggests that *active learning* is the most effective technique for learning as it sequences learning from the concrete to the abstract form of orientation (Duch et al, 2001). PBL offers an instructional approach to learning that challenges students to seek resolutions to messy real world (open-ended) problems (Murray-Harvey & Slee, 2000; Duch et al, 2001; Sonmez & Lee, 2003). Central to PBL is the ability to teach learners how to apply theoretical knowledge to professional contexts. In this sense PBL places an emphasis on theory and practice and is seen as valuable pedagogical strategy in those professions where there is a strong theory to practice nexus (Edwards and Hammer, 2007).

Since the general recognition of PBL as a useful pedagogical strategy there have been numerous attempts to define PBL, with many commentators expanding on the core structural characteristics that informed the early model of PBL as suggested by Barrows and Tamblyn (1980):

- Complex, real world situations that have no one right answer are the organising focus for learning;
- Students work in teams to confront the problem, identify learning gaps, and to develop solutions.
- Students gain new information through self-directed learning.
- Staff act as facilitators.
- Problems lead to the development of clinical problem-solving capabilities.

PBL has been adopted across a raft of professional programmes since its adoption in medical schools in the 1960s. Consequently the original definitions have come under scrutiny and been expanded to become less rigid in structure and enhanced by pedagogical principles such as knowledge transfer.

Boud (1985 as cited in Savin-Baden & Major, 2004, p. 4) outlines eight characteristics that are common in research that elaborate on the pedagogical understanding that underpins PBL:

1. An acknowledgement of the base of experience of learners.
2. An emphasis on students taking responsibility for their own learning.
3. A crossing of boundaries between disciplines.
4. An intertwining of theory and practice.
5. A focus on process rather than the product of knowledge acquisition.
6. A change in focus of tutors' role from that of instructor to that of facilitator.
7. A change in the focus from tutors' assessment of outcomes of learning to student self-assessment and peer assessment.
8. A focus on communication and interpersonal skills so that students understand that in order to relate their knowledge, they require skills to communicate with others, skills that go beyond their area of technical expertise.

The characteristics suggested by Boud demonstrate a distinct shift from the earlier teacher transmission approach to one that is student centred. The characteristics proposed by Savin-Baden (2000) are similar. She argues the characteristics of PBL align to contemporary teaching and learning theory.

Problem-Based Learning – characteristics & objectives

The fundamental objective of PBL is to equip students with transferable skills and knowledge that link school/university to professional life. It is the intention that PBL will provide students with life-long learning capabilities (Cambourne, 1998 as cited in Murray-Harvey and Slee, 2000). PBL is widely referred to as: focused, experiential based learning that is organised around the investigation, resolution and presentation of ill-structured and ill-defined real world problems (Kolmos, 2002; Murray-Harvey & Slee, 2000; Savin-Baden, 2000; Tan, 2007).

Furthermore, PBL is described as an instructional approach that shifts the classroom focus from passive to active learning, challenging students to 'learn to learn' in a collaborative environment (Peters, 2006; Tan, 2007). Kolmos (2002) asserts PBL enables students to draw upon their prior knowledge and skills while engaging in real-world problem solving contexts, arguing that this approach reinforces and allows for the transfer of knowledge into new uncertain situations.

Interdisciplinary science and technology: student led inquiry using PBL

The problem-based learning scenarios that students in the integrated curriculum: science and technology course considered and engaged with are based upon the model shown in figure 1 (modified from Aikenhead, 1991). After engaging with reviewing the nature of science and technology, coupled with minor standalone investigations the 3rd year students, in groups of three, undertook a five week collaborative group inquiry. The inquiry commenced with scoping problems or issues of personal significance; ensuring in the scoping exercise the inquiry would require a science investigation and understanding that would have a direct relationship and contribute to a technological solution. Figure 1 shows, that the problem/issue of this nature are first and foremost linked to people, noting we live in a technological rather than a scientific world. In presenting this illustration MacIntyre, Brears and Bhattacharya (2008) suggest, events (issues/problems) first enter the domain of technology and then on into the domain of traditional science where science content is learnt in a meaningful context. Finally it re-enters the domain of technology where the original (possibly superficial) understanding becomes more complex with additional learning. The process once again enters the realm of society as an informed in-depth understanding of the science content that has led to the development of the proposed technological solution.

For example in demonstrating the process in Fig 1, one group of students identified the ongoing severe damage to a seawall that protected residential property in a coastal city. Given the severity of the damage that included erosion, and posing a threat to residential and commercial property the students chose to research possible alternatives.

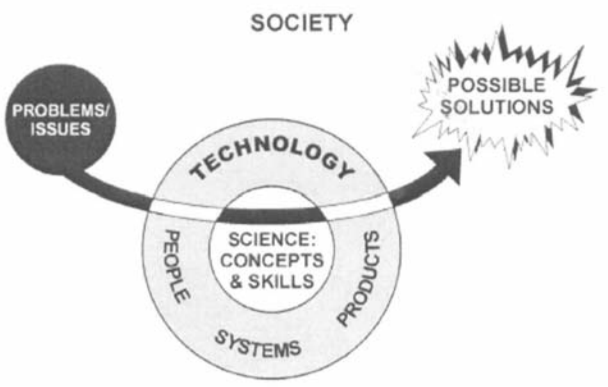

Figure 1. Integration of Science Technology and Society through PBL

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In order to develop a possible long term solution the students researched the wave patterns by consulting experts in the community that included engineers from the harbour board. Following on from this the students undertook a series of science investigations relating to the effectiveness and location of sea walls and groynes. For analysis purposes the investigations were all recorded using video technologies. This allowed the students to consider the scientific evidence to inform a possible technological outcome.

The students also interviewed local residents who had been long term residents before the port extension. From the interviews they were able to conclude that the extension had altered the wave pattern with greater levels of energy placing stress on the retaining wall. As a result of these in-depth investigations the students concluded the inquiry by proposing an extension to the inner shipping channel rock wall would alleviate the effects of the waves on the existing retaining wall. In proposing this solution they also recognised the powerful forces of nature that in the end may overcome any possible technological solution.

> Being involved in the whole process, problem identification to solution, allowed meaningful learning to occur. I found researching a problem that was both local and relevant provided the motivation to learn. I was able to associate with authentic and meaningful learning, rather than being told about the erosion at Westshore Beach. We were exploring the complex issue out of concern, considering the environmental and social impact. Because I was engaged in something of interest I wanted to learn and find out as much as I could. I can see how this type of inquiry would spark and maintain a child's interest and develop many skills such as undertaking a science investigation, developing scientific understanding and applying the knowledge to inform a technological outcome while authentic learning is occurring. In a supportive environment children can take ownership of their learning developing the metacognitive skills of synthesis, analysis and evaluation. Upon reflection it was impressive to see we had covered so much of the curriculum. I look forward to using PBL in my future teaching, particularly at the senior level of primary education (Student A, 2007).

Self reflection and evaluation

Reflection, reflective thinking or reflective practice has played a central role within teacher education and ongoing professional development for a considerable number of years, emerging from the work of Dewey (Maarof, 2007; Moon, 1999; Schon, 1987). Dewey (1933 as cited in Rodgers, 2002, p. 850) defined reflection as "the active, persistent and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it and the further conclusions to which it tends."

A common purpose for reflective commentary has been argued on the grounds that it engages teachers in a recurring cycle of critique, linking theory to practice (Schon, 1987). Osterman and Kottkamo (2004) argue reflective practice is a meaningful and effective professional strategy, in that it fosters personal learning and behavioural change. Schon's work on reflective practice examines the connections between thought and action as a key foundation of learning in which 'thinking and doing' are complimentary and embedded in professional practice. Schon argues, through reflection we "surface and criticise the tacit understandings that have grown up around repetitive experiences of a specialised practice, and can make new sense of…situations of uncertainty or uniqueness" (1983, p. 61). Through systematic inquiry and analysis it is a way for individuals to create meaningful and enduring change that will be helpful for effective teaching and learning in the complex 21st century classroom. Thus, reflective practice could be considered as a means of increasing critical ability and encouraging the adoption of a deep approach (Moon, 1999; Maarof, 2007).

Gorranson (2007) proposes PBL involves reflection in and on action that involves searching for knowledge, formulating solutions and evaluating the learning process. Schon (1987 as cited in Maarof, 2007) differentiates between reflection in action and reflection on action. Reflection in action is when a practitioner, who is often an expert, demonstrates the ability to think on one's feet, to improvise and deal with the unexpected intuitively. Reflection on action involves the practitioner reflecting and contemplating on the underlying implied understandings and assumptions that he or she has and further analyses them consciously in order to arrive at a deeper understanding of the role of the student and the teacher, the motivations and behaviours in the learning context (Maarof, 2007).

Studies by Hatton and Smith (1995 as cited in Maarof, 2007) identified four types of reflective writing; (a) descriptive writing, (b) descriptive reflection, (c) dialogic reflection, and (d) critical reflection. The first form, descriptive writing is described as a means of simply recording events and is not considered reflective. The second form, dialogic reflection contains an element of rationale or reasons based on evaluations and judgements. The third form is defined as writing that

reflects a dialogue with the self and shows evidence of the attempt to explore reasons and suggesting a form of 'thinking out loud'. The fourth form: critical reflection, concerns itself with advancing reasons and justifying decisions and events taking into account the broader social or political context (Maarof, 2007). However, according to Shermis (1993) and Maarof (2007), critical reflective analysis may be difficult for pre-service students as they have limited experiences in the classroom. The implication being that pre-service and novice teachers should be supported to reflect upon their learning.

Recognising the evolving role of the teacher and student in PBL

Throughout the extended inquiry students were made aware of the intention of the evolving roles of the teacher and student. Torp and Sage (2002) suggest a changing teacher and student role throughout the duration of the inquiry. They suggest increasing student ownership and self-directed learning as students are drawn into the problem with a lesser emphasis on the formal teaching aspect, to one that is supportive. The pedagogical approach here is that learning occurs by engaging in the real problems of practice, and by reflecting critically upon this active participation (Rogoff, 2003). As part of the assessment students were required to complete a self reflection and evaluation of the PBL process individually (see table 1). Students were not given any specific guidelines in writing their reflections beyond the rubric criteria itself and the suggestion to re-read a section of the integrated course notes pertaining to PBL (MacIntyre et al, 2008).

An important consideration when undertaking rubric design is determining the type of measurement to be used. Nitko (2004) proposes two contrasting rubric designs. According to Nitko, the holistic scoring rubric allows one to make a holistic judgement about the overall quality of the response. In contrast the analytical rubric allows one to evaluate specific dimensions of a student's response. Nitko (2004) suggests a blend of both the analytical and holistic rubric may occur. He refers to this as the annotated holistic rubric, suggesting that not all possible indicators have been developed.

Here it is suggested (see table 1) an annotated holistic scoring rubric design has been operationalised, as not all the possible characteristics were fully developed or identified in the rubric design. As a consequence not all the reflections presented examined the evolving roles of the teacher/student. This could be attributed to a number of factors such as, the non-specific instructions, the failure to become familiar with the readings identified prior to writing the self-evaluation or to the nature of the annotated holistic rubric design discussed.

SOLO, an acronym for the Structure of Learning Outcomes is a qualitative measure of learning (taxonomy) developed by Biggs and Collis (1982). This taxonomy contains five levels of increasingly complex levels of knowledge, ordered from incompetence to expertise commonly used in tertiary settings (Murray-Harvey & Slee, 2000). The five levels of the taxonomy can be used to describe student learning outcomes as: prestructural (incompetence, no meaning or relevant knowledge); unistructural (oversimplication, focus on one relevant aspect);

10-9 marks	8-7 marks	6-5 marks	4-3 marks	2-1 marks
Individual member **evaluates, self reflects** or **justifies** the processes/skills involved **in the PBL process.**	Individual member **evaluates, self reflects** or **justifies** the processes/skills involved in the PBL process. **Some key aspects of PBL missing.**	Individual member **evaluates, self reflects** or **justifies** the processes/skills involved in the PBL process. **Key aspects of the PBL process missing.**	**All key aspects of the PBL process are included** in the self reflection and evaluation.	Individual member **makes an attempt** to evaluate, self reflect or justify the processes/skills involved in the PBL process.
Provides **specific examples** from their experiences to support self reflection and evaluation.	Provides **specific examples** from their experiences to support self reflection and evaluation.	Provides **some examples** from their experiences to support self reflection and evaluation.	Individual member **lacks specific examples to support** self reflection and evaluation.	

Table 1. Section E – Assessment Criteria: Self Reflections and Evaluation of the PBL Process MacIntyre et al (2008)

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multistructural (relevant but unintegrated knowledge; relational (integrated, content restructured in terms of principles and concepts); extended abstract (generative, provides new data, critiques and questions content).

An examination of the rubric design (table 1) suggests the principles of the SOLO taxonomy are evident. This claim is made on the grounds that the rubric suggests increasing levels of complexity in understanding that inform the five point scale is evident. All self evaluation and evaluations of the PBL process were examined to identify the ‘evolving teacher and student role in problem-based learning’ using the descriptors develop by Biggs and Collis. Based on the scale advanced by Biggs and Collis it appears similar results to those reported in previous studies were recorded in that no more than 67% of students were coded no greater than level 3 (Bain et al, 1999). Previous studies suggest that student teachers initial attempts tend not to reach more developed levels of critical reflection; rather they take time to develop once engaged in actual classroom practice (Bain et al., 1999; Maarof, 2007).

The quotes below are exemplars of a larger data set (n=52). They have been selected because they offer insightful, vivid reflections of the evolving roles of the teacher/student; reflections that would contribute to a robust mental model being formulated that sit at the upper end of the SOLO taxonomy.

In the initial stages of the process we were provided with guidance and support. This guidance faded as we gained expertise and the lecturer took on a facilitator's role. To be totally honest I found the help and support of the lecturers throughout the entire process, even though the guidance faded, as it should, to be helpful and supportive….We were never given answers to problems…but given guidance by being provided with thought provoking questions that made us think about our thinking…I felt supported throughout the entire process by my peers and lecturers. This made for an enjoyable learning experience that will inform my future teaching practice particularly in the upper primary school level (Student A, 2008).

Throughout this process and according to Putnam (2001) I became a self-directed learner with the help from the lecturer gradually decreasing. We adopted a student-centred approach to this very “real world” problem of creating an inclusive playground for all children. The lecturer did not at any stage jump in and feed us information. Instead of giving us a direct answer to our questions he steered us by asking us open ended questions that caused us to think in a divergent manner while still focusing on our problem statement (Student B, 2008).

Throughout the investigation, our tutor questioned us on our original problem statement’s manageability/focus, leading to its adaptation. Guiding students in establishing the initial problem/objectives at the metacognitive level, not just providing information, provides a challenge, probing one’s knowledge/ reasoning is an essential aspect (Putnam, 2001). Questions of manageability, motivation and meaningfulness, modelled by our lecturer, were used within our group. Gradually withdrawing, our tutor allowed us more autonomy, empowering us through affirmation or metacognitive questioning as necessary (Torp & Sage, 2002). This sideline coaching gave us confidence to self-direct our learning, facilitating deeper levels of understanding and making it more meaningful (Student C, 2008).

When our tutor started to withdraw from interacting with our group, I found it a bit of a concern, as I wondered if we were on the right track. I now realise that in fact he was keeping an ever-watchful eye on us, and would have re-focused our group back on track if this was necessary. In effect he was modelling what we will have to do when we use PBL in our future classes; interact with the students, encourage independence and then assume a leadership aspect (Kain, 2003) (Student D, 2008).

Askwell-William, Murray-Harvey & Lawson (2006) stress the importance of students developing robust and transferable mental models in their training, they argue that without this, students will revert to earlier mental models. Developing robust mental models requires pre-service teachers to undertake ‘participatory experiences’ that exemplify sound practice to develop the practical skills, theoretical knowledge and dispositions necessary to critically reflect upon their practice. The reflections cited above identify the changing roles. Here it is suggested the pre-service teachers have now formulated a robust *mental model* that reflects sound PBL pedagogy.

O’Sullivan (2008) argues in comparing a single curriculum studies paper, pre-service students in the integrated curriculum paper failed to develop a robust personal construct to the same degree. He reports the inability to develop a robust personal construct can be partly attributed to the time lapse between the initial foundational technology curriculum course and integrated curriculum paper, identifying a minimum gap of 18 months. In addition O’Sullivan reports, pre-service teachers engaged in very limiting teaching or observations of either science or technology in their practicum, contributing to a less than rigorous school knowledge development. O’Sullivan in his conclusion raises issues that need further research. He raises an important question asking, ‘how

can teachers make the best use of an integrated curriculum when their own level of understanding the component parts are so weak'? (2008, p. 252). Here it's suggested, given the support and opportunity in facilitating PBL inquiry the beginning teacher would recall and enact the principles of the changing role of the teacher and student as the inquiry progresses in their own classroom.

Enacting Problem-Based Learning in middle schools

In examining the student self-evaluations and reflections (n =52) 34 students mentioned that PBL would be considered as a teaching strategy in the upper primary school level, Years 7 and 8 (commonly age 11-12) for a variety of reasons including: interest, ability to undertake extended inquiry and more complex inquiry as well as being motivating.

Manning and Bucher (2001) assert young adolescents are at a stage of development that sets them apart cognitively, physiology and emotionally from that of the child and adolescent. They identify young adolescents face interconnecting issues that are located in four distinct sections of society: family, neighbourhood, peer and ethical groups (2001). Manning and Bucher argue that as educators we must see beyond the four walls of the classroom and begin to understand how young adolescents develop in light of these communities.

Beane (2001; 2004) identifies that young adolescents are in a state of transition between the elementary and the more abstract senior school curriculum which is aligned to the activity of post schooling. Beane (2004) argues students in middle school should be exposed to learning experiences that engage students in exploratory type community based experiences. Making connections to the places we inhabit is an important component of well-being as it links the learning to the life-world of the students. PBL, it has been argued is characterised for capability through exploration rather than knowledge acquisition. Sonmez and Lee (2003) suggest PBL enhances thinking and learning skills and cognitive skills of students aligning to the constructivist view of learning. Accordingly, they argue that PBL enhances student interest and enjoyment as they engage in contexts that resemble real world situations. Thus, it appears that PBL as a teaching and learning strategy meets the social and educational needs of the pre-adolescent.

Conclusion and recommendations

This paper has drawn on the work of Huber and Hutchings (2008) arguing that teacher educators need to provide intentional learning experiences in order for Pre-service teachers to develop robust mental models that will transfer into classroom practice. The teaching staff at Massey University explored various curriculum designs concluding that PBL would provide for meaningful and engaging curriculum integration based on the understanding that Curriculum Integration is issue centred and not interest centred (Beane, 1997).

Within the context of evaluative research (Guba, 1981) described here it appears that an open-ended PBL experience was an appropriate pedagogical approach for engaging students in practical-based experiences and deep learning within the two curriculum disciplines. This paper has referred to research which proposes reflective thinking and practice has played a central role within teacher education for an extended period of time allowing for reflection. However, the research alludes that pre-service teachers do have difficulty, due to limited time in the classroom, to become proficient in reflective practice. With the adoption of the rubric for evaluating 'the evolving role of the teacher/student this report suggests similar results to previous research was evident. It was the students' lack of responses to the evolving role of the teacher and student that requires scaffolding to occur in future experiences. This findings support Guba and Lincoln's assertion of the importance of a reflective and iterative process found in evaluation inquiry.

Peters (2006) argues teacher educators need to make better connections between the learning at tertiary level and the 'real' world of teaching that reflects society. Sarason (1998 cited in Kain, 2003) offers an inspiring goal and a challenge for all educators when he describes, "I would want all children to have at least the same level and quality of curiosity and motivation to learn and explore that they had when they began schooling" (p. 69). Peters says an ongoing challenge for teacher educators is to ensure their own practice models pedagogy that allows for the development of their students' robust mental models. Engaging in PBL at a level where pre-service teachers identify their own issue/problems for inquiry, in teacher education courses has allowed students to demonstrate those aspirations detailed by Sarason. As students have reported, complexity thinking, meta-cognition, intrinsic motivation, self-directed learning, self reflection and collaborative skills have been operationalised within the context of the PBL investigation described. These skills, it has been argued are essential in meeting the social and educational needs of the pre-adolescent in a 21st century middle school classroom.

PBL is still in its infancy and largely unexplored within teacher education and classroom practice in New Zealand. Piaget's study of the nature of children at different ages provides valuable insights for educators into how children learn. For Piaget, the mental development of any child

consists of three biological stages of development: namely sensorimotor, symbolic (preconcrete-operational) and concrete operational. Each stage extends the preceding stage constructing cognition of a new level. During pre-adolescence, generally regarded as occurring between ages 10-14, the stage of formal operations emerges. Formal operation being defined as: thinking about thinking (metacognition), construct ideals, reason realistically about the future, and reason about contrary-to-fact propositions (Kellough & Kellough, 2003).

Further application in a variety of contexts needs to be undertaken in order to confirm the generalised results. When the requirements to meet the social and educational needs of the pre-adolescent are considered, an obvious next step is to engage PBL in the middle school teaching and learning environment. In the context of the New Zealand classroom, access to professionals through schemes such as the 'neighbourhood engineer scheme' funded by the Institute of Professional Engineers New Zealand enhances the prospect of connecting with the wider community to support meaningful inquiry.

Finally the words of one student are echoed in endorsing PBL as an effective teaching and learning strategy:

> Over all I think PBL has limitless possibilities in the middle school classroom. This paper (course) has inspired me and given me a much better understanding of curriculum integration involving science and technology. Together we researched an issue of personal interest, the heating and resulting sweating when riding with backpacks attached. We collaborated in how we might solve this problem, designing and completing science experiments in an attempt to record air flow patterns and measuring body sweat in order to design a backpack that would allow for cool air to be circulated between the body and the backpack frame. I trusted my partners to responsibly carry out their roles to a high standard, while they trusted me to do the same. Once we pooled our resources, I could make sense of, and get a fuller picture of where we were heading. Williams and Williams (1997) describes this process as independent studies coming together for group discussion, where "synthesis and application" (p. 94) takes place among group members. Problem based learning is intrinsically motivating. Part of this is due to wanting to do your best for your team, and part is due to personal satisfaction of seeing the investigation progress and make sense. According to Putnam (2001), "…the need for knowledge and skills becomes the goal for learning" (p. 5) (Student E, 2008).

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